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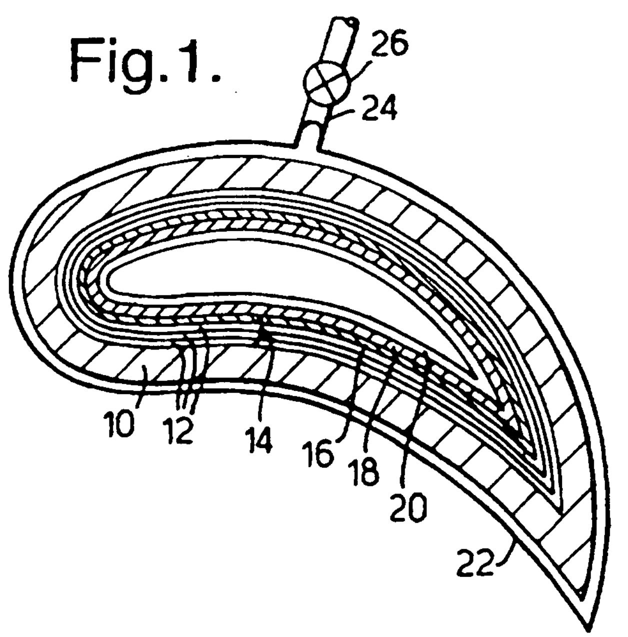
(54) Abstract Title
Manufacturing a ceramic matrix composite

(57) A method of manufacturing a ceramic matrix composite comprises forming a slurry comprising a ceramic sol, filler particles and a suspension medium such as water, and forming laminates of fibres (12). The laminates of fibres (12) are impregnated with the slurry and are stacked (14) on a mould (10). The stack (14) of laminates of fibres (12) is covered by a porous membrane (16), a breather fabric (18) and a vacuum bag (20). The vacuum bag (20) is evacuated and is heated to a temperature of 60°C for 10 hours to produce a ceramic matrix composite. The ceramic matrix composite is then heated to a temperature of 1200°C at atmospheric pressure to sinter the ceramic matrix composite.

Fig.1.



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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

Fig.1.

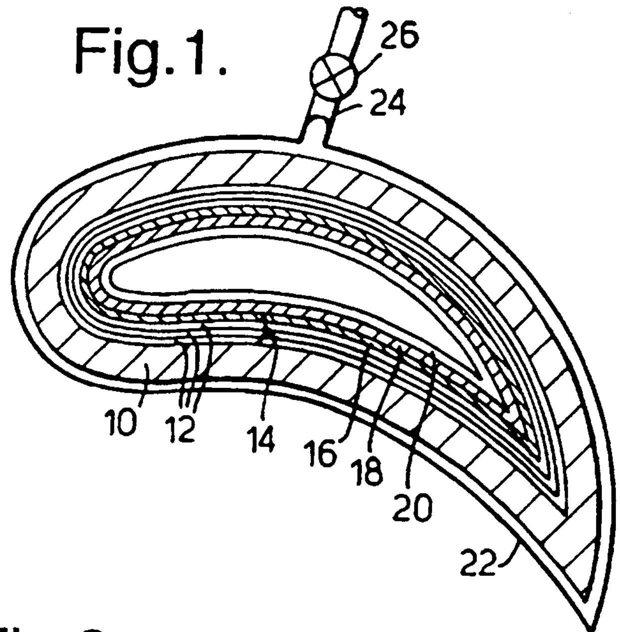


Fig.2.

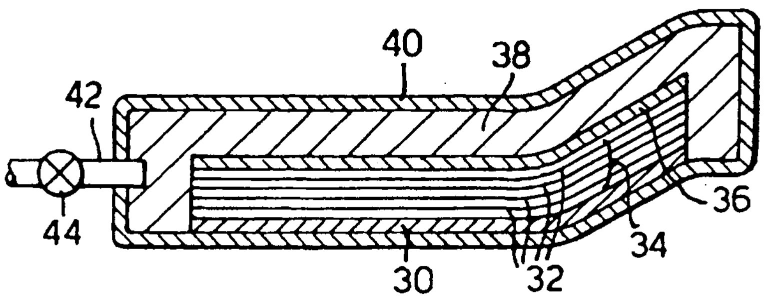


Fig.3.

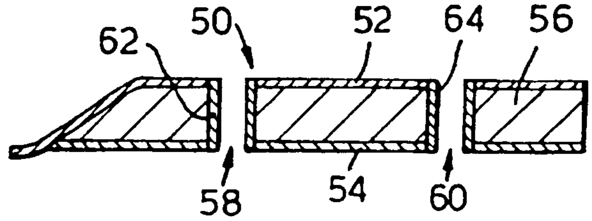
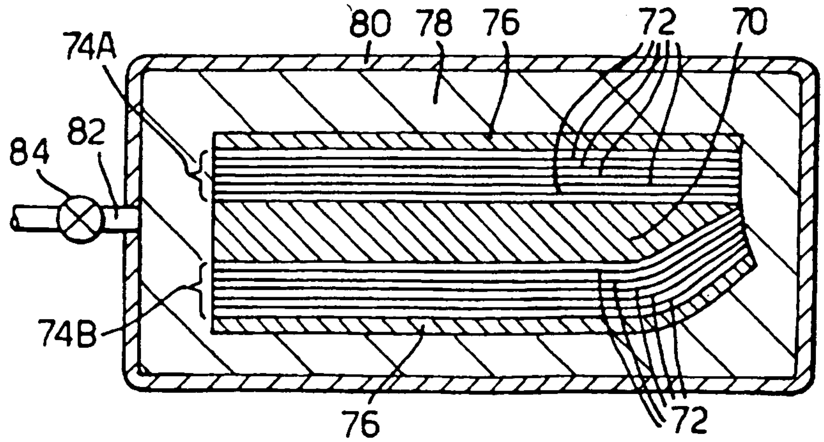


Fig.4.



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A METHOD OF MANUFACTURING A CERAMIC MATRIX COMPOSITE

The present invention relates to the manufacture of ceramic matrix composites which comprise reinforcing fibres in a ceramic matrix, particularly ceramic fibres in a ceramic matrix.

It is known to produce ceramic matrix composites by chemical vapour infiltration, by directed metal oxidation or by sol-gel processes.

The chemical vapour infiltration method comprises forming a fibre preform and then depositing a ceramic matrix on and between the fibres in the fibre preform. The ceramic matrix is deposited by decomposing a chemical compound in the vapour form and depositing the resulting ceramic onto the fibre preform. The chemical vapour infiltration method is a very expensive method and requires expensive apparatus, furthermore in some instances the chemical compounds which are to be decomposed are toxic. The chemical vapour infiltration method has to be performed at a relatively high temperature to decompose the chemical compound.

The directed metal oxidation method comprises forming a fibre preform and then growing a ceramic matrix on and between the fibres in the fibre preform. The ceramic matrix is grown by placing the fibre preform on the surface of a molten metal and oxidising the metal such that the metal oxide grows into the fibre preform. The directed metal oxidation method is also a very expensive method and requires expensive apparatus. Additionally there is always some unreacted metal which is difficult to remove. The directed metal oxidation method also has to be performed at a relatively high temperature to melt the metal.

The sol-gel method comprises either vacuum impregnation or filament winding. The filament winding method comprises passing each fibre through a container of the sol, winding the impregnated fibre on a mandrel of the desired shape, converting the sol to a gel and then heating to convert the gel to a ceramic matrix. The sol-gel method is cheaper than

the chemical vapour infiltration method and the directed metal oxidation method and also is performed at a relatively low temperature. The sol-gel method has a low yield and has large shrinkage of the ceramic matrix resulting in cracking of the ceramic matrix. Also multiple infiltration and densification cycles are required.

The present invention seeks to provide a novel method of manufacturing a ceramic matrix composite.

Accordingly the present invention provides a method of manufacturing a ceramic matrix composite comprising the steps of:-

(a) forming a slurry comprising a ceramic sol, filler material and a suspension medium,

(b) forming a plurality of laminates of fibres,

(c) applying the slurry to each of the plurality of laminates of fibres,

(d) stacking the plurality of laminates of fibres on a mould,

(e) applying pressure to the stack of laminates of fibres to remove the suspension medium from the slurry to solidify the ceramic sol and thereby produce a ceramic matrix composite.

Preferably step (e) comprises covering the stack with a porous membrane, covering the porous membrane with a breather fabric, covering the breather fabric with a vacuum bag and evacuating the vacuum bag to remove the suspension medium from the slurry to solidify the ceramic sol and thereby produce a ceramic matrix composite.

Preferably the vacuum bag is evacuated to a pressure less than 3000Pa and held at that pressure for about 10 hours.

Preferably the method comprises heating the stack during or after evacuation of the vacuum bag to encourage the solidification of the ceramic sol. Preferably the stack is heated to a temperature in the range 60°C to 150°C.

Preferably the method comprises pressure less sintering after evacuation of the vacuum bag.

Preferably the ceramic sol comprises silica, alumina or mullite particles and the filler material comprises silica, alumina or mullite particles. The filler material particles may have a diameter greater than 1 micron and the ceramic sol particles may have a diameter of about 40 nanometres.

Preferably the fibres comprise silica, alumina, mullite or a mixture of any two.

Preferably the mould is hollow and has an inner surface, the method comprising stacking the laminates of fibres on the inner surface of the hollow mould.

The mould may comprise a styrofoam mould. The mould may define an aerofoil shape.

The fibres may comprise mullite or mullite and alumina, the ceramic sol comprises silica and the filler material comprises alumina.

The present invention will be more fully described by way of example with reference to the accompanying drawings, in which:-

Figure 1 shows an apparatus for use in manufacturing a ceramic matrix composite according to the present invention.

Figure 2 shows an apparatus for use in manufacturing a sandwich structure comprising a ceramic matrix composite manufactured according to the present invention.

Figure 3 shows a sandwich structure comprising a ceramic matrix composite manufactured according to the present invention.

Figure 4 shows a further apparatus for use in manufacturing a sandwich structure comprising a ceramic matrix composite manufactured according to the present invention.

A method of manufacturing a ceramic matrix composite, as shown in figure 1, comprises forming a slurry comprising a ceramic sol, filler material and a suspension medium. The ceramic sol comprises any suitable ceramic for example silica, alumina, mullite, aluminosilicate, silicon nitride,

silicon carbide etc. The filler material comprises particles of any suitable ceramic for example silica, alumina, mullite, silicon nitride, silicon carbide and the filler material particles are relatively large compared to the ceramic sol. The filler material particles have a diameter greater than 1 microns. The ceramic sol comprises particles having a diameter of the order of 40 nanometres. The suspension medium comprises for example water. The suspension medium has the characteristic of being removable from the slurry by the application of a vacuum or by the combination of application of a vacuum and heat.

A number of laminates, or plies, of reinforcing fibres are formed. The laminates of fibres may be two dimensional weaves of fibres etc. The fibres may be any suitable fibres for reinforcing a ceramic matrix for example silica, alumina, mullite, aluminosilicate, silicon carbide, silicon nitride or other ceramic fibres.

Each of the laminates of fibres is impregnated with the slurry and the slurry impregnated laminates of fibres 12 are stacked one on top of the other on a mould 10 to form a stack 14. The stack 14 is covered by a porous membrane 16, for example a wet filter paper or a perforated plastic sheet. The porous membrane 16 is covered by a breather fabric or bleeder pack 18 and then the breather fabric 18 is covered by a vacuum bag 20.

In this example the mould 12 comprises a hollow styrofoam mould and the slurry impregnated laminates of fibres 12 are stacked one on top of the other on the interior surface of the mould 10. The vacuum bag 20 is sealed to an outer bag 22. However, if the slurry impregnated laminates of fibres 12 are stacked on the outer surface of the mould 10 the vacuum bag 20 is sealed to the outer surface of the mould 10.

The interior of the vacuum bag 20 is then connected to a vacuum pump 26 via a pipe 24. The interior of the vacuum bag 20 is then evacuated to a suitably low pressure to consolidate the ceramic matrix composite. The interior of

the vacuum bag 20 is evacuated to a pressure less than about 30mbar (3000Pa). The application of the low pressure on the slurry impregnated laminates of fibres 12 causes the suspension medium to be removed from the ceramic sol and hence the ceramic sol solidifies causing the ceramic matrix to harden. The application of the low pressure causes the suspension medium to be drawn from the slurry impregnated laminates of fibres 12 through the porous membrane 16 into the breather fabric 18.

The slurry impregnated laminates of fibres 12 are either heated during or after evacuation of the vacuum bag 20, in an autoclave, to encourage the removal of suspension medium and hence the solidification of the ceramic sol. It may be possible to manufacture the ceramic matrix composite at room temperature without the application of heat, but it is preferred to provide heat during or after evacuation to reduce the manufacturing time. It is preferred to heat the slurry impregnated laminates of fibres 12 to a temperature in the range 60 to 150°C subject to temperature limitations of the mould.

The resulting ceramic matrix composite is then pressure less sintered by heating to a relatively high temperature at atmospheric pressure to complete the processing.

The advantages of the present invention are that the method of manufacturing ceramic matrix composites is relatively cheap in terms of processing costs and apparatus compared to the chemical vapour infiltration and directed metal oxidation methods. Additionally the method of the present invention enables ceramic matrix composites to be produced relatively quickly. The advantages compared to conventional sol-gel methods is a reduction in the number of reinfiltration cycles, and a rigid and durable green body is produced.

<u>Example 1.</u>

A slurry comprising a ceramic sol of silica, filler particles of alumina and water was formed. Laminates of 8 harness satin weave mullite fibres, sold under the trade name Nextel 550 by Minnesota Mining and Manufacturing Company, or laminates of 8 harness satin weave alumina and mullite fibres, sold under the trade name Nextel 720 by Minnesota Mining and Manufacturing Company were impregnated with the ceramic sol. The impregnated laminates of fibres 12 were stacked 14 on the mould 10 and covered by a porous membrane 16, a breather fabric 18 and a vacuum bag 20.

The vacuum bag 20 was evacuated to a pressure less than 30mbar (3000Pa) and was heated to a temperature of 60°C for 10 hours to produce an alumina/silica matrix composite. The alumina/silica matrix composite was then heated to a temperature of 1200°C at atmospheric pressure to sinter the alumina/silica matrix composite.

The hollow mould shown in figure 1 was used to produce an aerofoil shaped ceramic matrix composite article for example a blade or vane for a compressor or turbine of a gas turbine engine. The method may also be used to make other ceramic matrix composite articles using suitably shaped moulds.

It is also possible to manufacture a ceramic matrix composite by forming a slurry comprising a ceramic sol, filler material and a suspension medium. The ceramic sol comprises any suitable ceramic for example silica, alumina, mullite, aluminosilicate, silicon nitride, silicon carbide etc. The filler material comprises particles of any suitable ceramic for example silica, alumina, mullite, silicon nitride, silicon carbide and the filler material particles are relatively large compared to the ceramic sol. The filler material particles have a diameter greater than 1 microns. The ceramic sol comprises particles having a diameter of the order of 40 nanometres. The suspension medium comprises for example water.

A number of laminates, or plies, of reinforcing fibres are formed. The laminates of fibres may be two dimensional weaves of fibres etc. The fibres may be any suitable fibres for reinforcing a ceramic matrix for example silica, alumina, mullite, aluminosilicate, silicon carbide, silicon nitride or other ceramic fibres.

Each of the laminates of fibres is impregnated with the slurry and the slurry impregnated laminates of fibres are stacked one on top of the other on a mould to form a stack. The mould is placed in an autoclave and the autoclave is evacuated to a pressure less than 30mbar (3000Pa) and is heated to a temperature of 60°C for 10 hours to produce a ceramic matrix composite. The ceramic matrix composite is then heated to a temperature of 1200°C at atmospheric pressure to sinter the ceramic matrix composite. The application of the low pressure on the slurry impregnated laminates of fibres causes the suspension medium to be removed from the ceramic sol and hence the ceramic sol solidifies causing the ceramic matrix to harden. The application of the low pressure causes the suspension medium to be drawn from the slurry impregnated laminates of fibres.

The slurry impregnated laminates of fibres are either heated during or after evacuation of the autoclave, to encourage the removal of suspension medium and hence the solidification of the ceramic sol. It may be possible to manufacture the ceramic matrix composite at room temperature without the application of heat, but it is preferred to provide heat during or after evacuation to reduce the manufacturing time. It is preferred to heat the slurry impregnated laminates of fibres to a temperature in the range 60 to 150°C subject to temperature limitations of the mould.

The composition of the slurry is selected such that as the suspension medium is removed from the slurry the ceramic solidifies on the fibres to form the ceramic matrix without the formation of cracks in the ceramic matrix.

A sandwich structure 50, as shown in figure 3, comprises two layers 52 and 54 of a ceramic matrix composite with a layer 56 of ceramic filler arranged between the two layers 52 and 54 of ceramic matrix composite. The sandwich structure 50 has a plurality of apertures 58 and 60 to receive bolts whereby the sandwich structure 50 may be attached to other components. The apertures 58 and 60 are provided with ceramic tubes 62 and 64, which are arranged coaxially with the apertures 58 and 60 respectively, to reduce wear around the apertures 58 and 60.

The sandwich structure 50 is manufactured by firstly making the layers 52 and 54 of ceramic matrix composite.

The method of manufacturing the layer 52 of ceramic matrix composite, is shown in figure 2, and comprises forming a slurry comprising a ceramic sol, filler material and a suspension medium. The ceramic sol comprises any suitable ceramic for example silica, alumina, mullite, aluminosilicate, silicon nitride, silicon carbide etc. The filler material comprises particles of any suitable ceramic for example silica, slumina, mullite, aluminosilicate, silicon nitride, silicon carbide and the filler material particles are relatively large compared to the ceramic sol. The filler material particles have a diameter greater than 1 micrometer. The ceramic sol comprises particles having a diameter of the order of 40 nanometres. The suspension medium has the characteristic of being removeable from the slurry by the application of a vacuum or by the combination of application of a vacuum and heat.

A number of laminates, or plies, of reinforcing fibres are formed. The laminates of fibres may be two dimensional weaves of fibres etc. The fibres may be any suitable fibres for reinforcing a ceramic matrix for example silica, alumina, mullite, aluminosilicate, silicon carbide, silicon nitride or other ceramic fibres.

Each of the laminates of fibres is impregnated with the slurry and the slurry impregnated laminates of fibres 32 are stacked one ontop of the other on a mould 30 to form a stack

34. The stack 34 is covered by a porous membrane 36, for example a wet filter paper or a perforated plastic sheet. The porous membrane 36 is covered by abreather fabric or bleeder pack 38 and then the breather fabric 38 is covered by a vaccum bag 40. The vacuum bag 40 is sealed around the mould 30.

The interior of the vacuum bag 40 is then connected to a vaccum pump 44 <u>via</u> a pipe 42. The interior of the vacuum bag 40 is then evacuated to a suitably low pressure to consolidate the ceramic matrix composite. The interior of the vacuum bag 40 is evacuated to a pressure less than about 30mBar (3000Pa). The application of the low pressure on the slurry impregnated laminates of fibres 32 causes the suspension medium to be removed from the ceramic sol and hence the ceramic sol solidifies causing the ceramic matrix to harden. The application of the low pressure causes the suspension medium to be drawn from the slurry impregnated laminates of fibres 32 through the porous membrane 36 into the breather fabric 38.

The slurry impregnated laminates of fibres 32 are either heated during or after evacuation of the vacuum bag 40, in an autoclave, to encourage the removal of suspension medium and hence the solidification of the ceramic sol.

The resulting ceramic matrix composite is then pressure less sintered by heating to a realtively high temperature at atmospheric pressure. The ceramic matrix composite layer 52 is then machined to size and apertures drilled. To reduce porosity of the ceramic matrix composite layer 52, the ceramic matrix composite 52 is infiltrated with ceramic sol by imersing in a bath of ceramic sol and applying a vacuum. The ceramic matrix composite 52 is then reheated to a relatively high temperature.

The same process is used to manuacture the layer 54 of ceramic matrix composite.

The two layers 52 and 54 are then assembled to define the predetermined shape, or profile, of the component, or article. Ceramic tubes 63,64 are inserted coaxially in the

apertures 58 and 60. The open ends and edges of the assembly are sealed and a ceramic filler 56 is arranged into the space defined between the two ceramic matrix composite layers 52 and 54. The ceramic filler is allowed to cure at room temperature and finally the sandwich structure is heated in an autoclave at a relatively high temperature to produce the finished sandwich structure 50. The ceramic filler may be castable ceramic filler, a foamed ceramic etc for example foamed alumina, low density aluminosilicate insulation etc.

<u>Example 2</u>

A slurry comprising alumina and silica powders and water was formed, the loading of solids was 40 vol% and the ratio of alumina to silica was 95 to 5 by volume. Twelve laminates of 8 harness satin weave and mullite fibres, sold under the trade name Nextel 720 by Minnesota Mining and Manufacturing Company, were impregnated with the ceramic slurry to make each layer 52,54 of ceramic matrix composite. The impregnated laminates of fibres 32 were stacked 34 on the mould 30 and covered by porous membrance 36, a breather fabric 38 and vacuum bag 40.

The vacuum bag 40 was evacuated to a pressure less than 30 mbar (3000Pa) and was heated to a temperature of 40°C for 12 hours to produce an alumina/silica matrix composite layer 52,54. The alumina/silica matrix composite layer 52,54 was then heated to a temperature of 1250°C for 4 hours to sinter the alumina/silica matrix composite layers 52,54.

The layers 52,54 were then machined to size and apertures 58 were drilled.

The layers 52,54 were immersed in an alumina sol bath, then evacuated and refired at 900°C for 1 hour. The immersing in the alumina sol bath was repeated until the porosity was reduced sufficiently. The layers 52,54 are finally heated to 1250°C for 1 hour.

The layers 52,54 were assembled into position so that the apertures 58,60 are coaxial and alumina tubes 62 and 64 were inserted coaxially into the apertures 58,60 respectively.

The open ends and edges between the layers 52 and 54 were sealed, for example using polyester tape, and a wet mix of a castable ceramic filler 56 was vibrocast into the space between the layers 52 and 54. The ceramic filler 56 was allowed to cure at room tempeatue for 12 hours. The sandwich structure 50 was then heated in an autoclave to a tempeature of 1200°C for 1 hour to produce the finished component, or article.

An alternative method of manufacturing the sandwich structure 50, shown in figure 4, comprises using a shaped ceramic filler 56 as a mould 70 and manufacturing layers 52,54 of ceramic matrix composite on the surfaces of the ceramic filler 56, such that the ceramic matrix composite layers 52 and 54 and ceramic filler 56 form the sandwich structure 50.

The sandwich structure 50 is manufctured by firstly making the ceramic filler to the requited shape so that it forms a mould 70. For example foamed alumina may be machined to the required shapes.

A number of laminates of reinforcing fibres are formed, each of the laminates of fibres is impregnated with a slurry and the slurry impregnated laminates of fibres 72 are stacked one on top of the other on the mould 70 to form stacks 74A,74B on the surfaces of the mould 70. The stacks 74A,74B are covered with porous membranes 76, the porous membranes 76 are covered by a breather fabric 78 and the breather fabric 78 is covered by a vacuum bag 80. The vacuum bag 80 is sealed around the whole assembly.

The interior of the vacuum bag 80 is then connected to a vacuum pump 84 <u>via</u> a pipe 82. The interior of the vacuum bag 80 is then evacuated to a suitably low pressure as discussed

previously to consolidate the ceramic matrix composite layers as discussed previously.

Thus in this case the ceramic matrix composite layers 52,54 are formed integrally with the mould to form the sandwich structure 50.

Claims:-

1. A method of manufacturing a ceramic matrix composite comprising the steps of:-

(a) forming a slurry comprising a ceramic sol, filler material and a suspension medium,

(b) forming a plurality of laminates of fibres,

(c) applying the slurry to each of the plurality of laminates of fibres,

(d) stacking the plurality of laminates of fibres on a mould,

(e) applying pressure to the stack of laminates of fibres to remove the suspension medium from the slurry to solidify the ceramic sol and thereby produce a ceramic matrix composite.

2. A method as claimed in claim 1 wherein step (e) comprises covering the stack with a porous membrane, covering the porous membrane with a breather fabric, covering the breather fabric with a vacuum bag and evacuating the vacuum bag to remove the suspension medium from the slurry to solidify the ceramic sol and thereby produce the ceramic matrix composite.

3. A method as claimed in claim 2 wherein step (e) comprises evacuating the vacuum bag to a pressure less than 3000 Pa and holding at that pressure for about 10 hours.

4. A method as claimed in claim 2 or claim 3 comprising heating the stack during or after evacuation of the vacuum bag to encourage the solidification of the ceramic sol.

5. A method as claimed in claim 4 comprising heating the stack to a temperature in the range 60°C to 150°C.

6. A method as claimed in any of claims 2 to 5 comprising pressure less sintering after evacuation of the vacuum bag.

7. A method as claimed in any of claims 1 to 6 wherein the ceramic sol comprises silica, alumina or mullite particles and the filler material comprises silica, alumina or mullite particles.

8. A method as claimed in claim 7 wherein the filler material particles have a diameter greater than 1 micron.

9. A method as claimed in claim 7 or claim 8 wherein the ceramic sol particles having a diameter of about 40 nanometres.

10. A method as claimed in any of claims 1 to 9 wherein the fibres comprise silica, alumina, mullite or a mixture of any two.

11. A method as claimed in any of claims 1 to 10 wherein the mould is hollow and has an inner surface, the method comprising stacking the laminates of fibres on the inner surface of the hollow mould.

12. A method as claimed in any of claims 1 to 11 wherein the mould comprises a styrofoam mould.

13. A method as claimed in any of claims 1 to 12 wherein the mould defines an aerofoil shape.

14. A method as claimed in any of claims 1 to 13 wherein the fibres comprise mullite or mullite and alumina, the ceramic sol comprises silica and the filler material comprises alumina.

15. A method of manufacturing a ceramic matrix composite substantially as hereinbefore described with reference to Figure 1 of the accompanying drawings.

16. A ceramic matrix composite article as produced by a method as claimed in any of claims 1 to 15.

17. A method of manufacturing a sandwich structure comprising at least two layers of ceramic matrix composite and a ceramic filler arranged between the at lest two layers of ceramic matrix composite, the method comprising the steps of:

a) manufacturing each of the at least two layers of ceramic matrix composite using the steps of:

i) forming a slurry comprising a ceramic sol, filler material and a suspension medium,

ii) forming a plurality of laminates of fibres,

iii) applying the slurry to each of the plurality of laminates of fibres,

iv) stacking the plurality of laminates of fibres on a mould,

v) applying pressure to the stack of laminates of fibres to remove the suspension medium from the slurry to solidify the ceramic sol and thereby produce a ceramic composite layer,

b) arranging the at least two layers of ceramic matrix composite into a predetermined shape such that there is a space between the at least two layers of ceramic matrix composite,

c) filling the space between the at least two layers of ceramic matrix composite with a ceramic filler material,

d) heating the at least two layers of ceramic matrix composite and ceramic filler material to produce the sandwich structure.

18. A method of manufacturing a sandwich structure comprising at least two layers of ceramic matrix composite and a ceramic filler arranged between the at least two layers of ceramic matrix composite, the method comprising the steps of:

a) forming a mould from a ceramic filler material to a predetermined shape, the mould having spaced apart surfaces,

b) manufacturing each of the at lest two layers of ceramic matrix composite using the steps of:

i) forming a slurry comprising a ceramic sol, filler material and a suspension medium,

ii) forming a plurality of laminations of fibres,

iii) applying the slurry to each of the plurality of laminates of fibres,

iv) stacking the plurality of laminates of fibres on the mould, the at least two layers of ceramic matrix composite being formed on the spaced apart surfaces of the mould,

v) applying pressure to the stack of laminates of fibres to remove the suspension medium from the slurry to solidify the ceramic sold and thereby produce ceramic matrix composite layers on the ceramic filler material.

19. A method as claimed in claim 18 or claim 19 wherein step (e) comprises covering the stacks with a porous membrane, covering the porous membrane with a breather fabric, covering the breather fabric with a vacuum bag and evacuating the vacuum bag to remove the suspension medium from the slurry to solidify the ceramic sol and thereby produce the ceramic matrix composite.

20. A method as claimed in claim 19 wherein step (e) comprises evacuating the vacuum bag to a pressure less than 3000 Pa and holding at that pressure for about 10 hours.

21. A method as claimed in claim 19 comprising heating the stack during or after evacuation of the vacuum bag to encourage the solidification of the ceramic sol.

22. A method as claimed in claim 21 comprising heating the stack to a temperature in the range 40°C to 150°C.

23. A method as claimed in any of claims 17 to 22 comprising pressure less sintering after evacuation of the vacuum bag.

24. A method as claimed in any of claims 17 to 22 wherein the ceramic sol comprises silica, alumina or mullite particles and the filler material comprises silica, alumina or mullite particles.

25. A method as claimed in claim 24 wherein the filler material particles have a diameter greater than 1 micron.

26. A method as claimed in claim 24 wherein the ceramic sol particles having a diameter of about 40 nanometres.

27. A method as claimed in any of claims 17 to 26 wherein the fibres comprise silica, alumina, mullite or a mixture of any two.

28. A method as claimed in any of claims 17 to 27 wherein the mould is hollow and has an inner surface, the method comprising stacking the laminates of fibres on the inner surface of the hollow mould.

29. A method as claimed in claim 17 wherein the mould comprises a styrofoam mould.

30. A method as claimed in any of claims 17 to 29 wherein the fibres comprise mullite or mullite and alumina, the

ceramic sol comprises silica and the filler material comprises alumina.

31. A method of manufacturing a sandwich structure substantially as hereinbefore described with reference to Figures 2 and 3 of the accompanying drawings.

32. A method of manufacturing a sandwich structure substantially as hereinbefore described with reference to figures 3 and 4 of the accompanying drawings.

33. A sandwich structure as produced by a method as claimed in any of claims 17 to 32.

The Patent Office 18

INVESTOR IN PEOPLE

Application No: GB 9926460.8
Claims searched: all
Examiner: R C Squire
Date of search: 22 November 1999

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): C1J, B5N, F1V

Int Cl (Ed.6): B32B, C04B, F01D

Other: Online WPI, EPODOC

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	WO 93/10056A ROLLS-ROYCE	
A	US 4936939 WOOLUM	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.